

**AUDIO RADIATOR WITH RADIATOR FLEXURE MINIMIZATION AND VOICE  
COIL ELASTIC ANTI-WOBBLE MEMBERS**

5 CROSS REFERENCE

This application claims priority from US provision application having serial number 60/405,416 filed August 21, 2003.

BACKGROUND OF THE INVENTION

10 Field of the Invention

This invention relates to passive radiators and loud speakers, in particular to the construction of same with minimization of flexure of the radiator and wobble minimization of the voice coil throughout the full range of inner and outer travel of the radiator during operation.

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Description of the Related Art

In an audio speaker, or transducer, the closer together the points on the speaker frame, or basket, to which the suspension and spider are connected the greater the possibility of rocking, or wobble of the voice coil tube, or bobbin, with respect to the magnet during operation of the speaker. In a conventional speaker, the suspension is attached between the mouth of the basket and the outer diameter of the cone with the spider deeper in the basket beneath the surround. Wobble of the voice coil results from flexing of the speaker cone during operation as opposed to an even push or pull being exercised by the voice coil around the circumference where it connects to the speaker cone. When the cone is flexed, the upper end of the voice coil tube where it attaches to the cone and the lower end of that tube surrounding the magnet are no longer directly above each other with respect the central axis of the speaker. Stated another way, when wobble occurs the central axis of the voice coil tube momentarily is

not coincident with the central axis of the speaker, i.e., the central axis of the voice coil tube is not parallel to the central axis of speaker. Thus, when the cone flexes and the voice coil wobbles, unwanted distortions occur in the sound waves being reproduced by the speaker. Such distortion effects are often audible to the listener. Since the human  
5 hear does not have a flat response to all frequencies, the audio frequency where the mechanical distortion occurs and the percentage of distortion created determines whether or not the distortion created is audible to the listener.

In U.S. Patent 5,323,469, Scholz proposed the addition of a substantially conical  
10 stabilizing element between the underside of the speaker cone and the tube on which the voice coil is wound. In the Scholz configuration, the center of the cone is attached to the upper end of the voice coil tube and the conical stabilizing element is attached to the voice coil tube about one third the length of that tube below the connection point of the tube with the speaker cone. Additionally, a conventional spider is connected  
15 between the speaker frame and the voice coil tube at the point where the conical stabilizing element attaches to the voice coil tube. While this may present some improvement in the distortion level, the forces on the cone and voice coil presented by the spider remains uneven and can still produce flexing of the speaker cone resulting in differing degrees of distortion through out the travel of the cone and voice coil.

## SUMMARY OF THE INVENTION

The present invention overcomes the drawbacks of the prior art by providing a generally linear response by configuring two elastic members opposite one another so that any non-linearity in the spring constant between an outward displacement versus  
25 an inward displacement are substantially cancelled. The present invention provides a pseudo linear spring constant throughout the central range of travel of the cone and voice coil. This minimizes the flexing of the cone and the wobble of the voice coil tube.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a-1c are each a profile slice of the center of a typical prior art speaker with the cone in either the maximum extended, the rest or the maximum retracted position, respectively;

Figures 2a-2c are each a profile slice of the center of a speaker of the basic  
5 structure shown in Figs. 1a-1c for one embodiment of the present invention;

Figures 3a-3c are each a profile slice of the center of a speaker of the structure shown in Figs. 2a-2c with the cone replaced with a flat baffle for a second embodiment of the present invention;

Figures 4a-4c are each a profile slice of the center of a speaker with a concave  
10 cone for a third embodiment of the present invention; and

Figures 5a-5c are each a profile slice of the center of a speaker with a concave cone having an open center hole with a center pillar of the magnet extending upward through that hole for a fourth embodiment of the present invention.

## 15 DETAILED DESCRIPTION OF THE PRESENT INVENTION

The flexing of the cone, causing the cone to change shape, in different positions as the cone is driven is related directly to the composition of the cone material, with the dynamic characteristics of the cone material responsible for the flexing which can only be overcome by the selection of a different material for the cone. However, if the  
20 flexing of the cone is caused by the geometry of the overall speaker design, the flexing of the cone can be overcome by configuring the cone, flexible surround and resilient spider of the speaker such that the resultant force(s) that cause the unwanted flexing of the cone are cancelled at points on the cone where the spider and/or the surround attach to the cone (i.e., the forces are balanced before they cause flexure of the cone)  
25 for all positions through which the cone is driven.

In speaker design, when the voice coil is at rest the shape of the cone is considered the reference shape that is determined by the static forces and weight of the various components of the speaker, including the surround and spider. To minimize

distortion of the cone and wobble of the voice coil, the at rest shape is the desired shape regardless of the position of the cone. However, conventional speakers do not balance the forces for all positions that the cone goes through as it travels. Not only does the flexing of the cone and wobble of the voice coil cause distortion in the sound reproduction of the speaker, it will, in time, cause failure of the cone as a result of the life cycle of the cone material from the varying stresses.

Figures 1a-1c are each a profile slice of the center of a typical prior art speaker (shown here as a low profile speaker) with the cone in the maximum extended, the rest and the maximum retracted position, respectively. In each of these figures the speaker includes basket 2, magnet assembly 4, cone 6, surround 8, spider 10, voice coil tube 12 and voice coil 14. In Figure 1b the speaker is unenergized with the rest position of the cone 6 and voice coil 14 being determined by the weight and static elasticity of cone 6, surround 8, spider 10 and voice coil tube 12 since no electrical sign is applied to voice coil 14.

When cone 6 is in any position other than the at rest position of Figure 1b, the forces presented by surround 8 and spider 10 and the resilience, or lack there of, of cone 6 come into play to balance out the vertical motor force  $F_1$ . As can be seen from Figures 1a and 1b, the tensile forces presented by spider 10 ( $T_1$ ) and surround 8 ( $T_2$ ) are not parallel to motor force  $F_1$ , therefore there is both vertical and horizontal components of each of those forces with only the vertical components balancing motor force  $F_1$ .

In Figure 1a, for the speaker design of the example shown there, when cone 6 is at the maximum outward displacement, the tensile force  $T_1$  of the spider has a downward vertical component and an outward horizontal component with the horizontal component being substantially greater than the vertical component. Additionally, the horizontal component of  $T_1$  on one side of the speaker is balance by the horizontal

component of T1 on the other side of the speaker. Thus, since T1 is not parallel to the segment of cone 6 between points A and B a bending moment will be created at point B. Since the horizontal component of T1 is greatest, the bending moment B1 at point B of cone 6 increases the included angle at point B. Similarly, the tensile force T2 of surround 10 presents an upward vertical component and an outward horizontal component with T2 not being parallel to the segment of cone 6 between point A and the point of attachment of surround 8 with the vertical component being much greater than the horizontal component. The vertical force component of T2 being greater causes a bending moment at point A of cone 6 that reduces the included angle at point A. The extent to which the angles at points A and B change is also dependent on the tensile strength and flexibility of cone 6. The changing of these angles can also cause distortion of the surface of cone 6 at points other than A and B which cause voice coil tube 12 to be displaced relative to the central axis of basket 2 as described above.

In Figure 1c, for the speaker design of the example shown there, when cone 6 is at the maximum inward displacement the tensile force T1 of the spider has an upward vertical component and an outward horizontal component with the horizontal component being substantially greater than the vertical component. Since the horizontal component of T1 is greatest, the bending moment at point B of cone 6 increases the included angle at point B. Similarly, the tensile force T2 of surround 10 presents an upward vertical component and an outward horizontal component. Whether or not the included angle at point A changes depends on whether force T2 is parallel to the segment of cone 6 between point A and the point of attachment of surround 8. If T2 is parallel to that segment, then the included angle at point A does not change. If T2 is not parallel to that segment of cone 6, the change in the included angle at point A depends on which of the horizontal and vertical components of force T2 is greatest. If the horizontal component of is greatest, the included angle at point A will increase; alternatively, if the vertical component is greatest, the included angle at point A will decrease. Any changes to the shape of cone 6 in the inward most position

has a different effect on the distortion of cone 6 and thus on the position of voice coil tube 12 relative to the central axis of the speaker basket 2. This variation of the position of voice coil tube 12 for different positions of cone 6 is defined as the wobble of voice coil tube 12.

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The present invention provides a speaker design wherein the forces on the cone are balanced at all times throughout the travel of the cone. For the first embodiment of the present invention, the basic structure of the speaker of Figures 1a-1c is modified. Figure 2a shows cone 6 in the maximum outward position and since the basic structure here is the same as Figs 1a-1c, the same reference numbers are used. The differences in Figures 2a-2c with respect to Figures 1a-1c is the inclusion of an outer spider 10' that is similar to spider 10 in Figs. 1a-1c, and an inner spider 10" between point A and the top of magnet 4. It can be seen that both spider 10' and 10" apply a tensile force to point A of cone 6 on both sides of the center slice of the speaker which is the same for any center slice taken through the speaker.

In this configuration, on the left side outer spider 10' applies force T5 on point A and inner spider 10" applies force T3 on point A. Similarly on the right side of the speaker, outer spider 10' applies force T6 on point A and inner spider 10" applies force T4 on point A. Each of forces T3, T4, T5 and T6 have both a vertical and a horizontal component with spiders 10' and 10" being selected to balance the horizontal component of force on point A on both sides of the speaker in these views and totally around the speaker. That is, the horizontal outward component of T5 is equal to the inner horizontal component of T6, and the horizontal components of T2 and T4 are similarly balanced. By balancing the horizontal forces at point A on both sides of the speaker where the forces are applied, the result is no, or a very small bending moment at point B all around the speaker, unlike the prior art where the horizontal forces are balanced from the opposite side of the speaker (i.e., 180° around the speaker) as shown in Figs. 1a-1c. While spiders 10' and 10" are discussed as being separate, they

could be implemented as a single spider with point A of the cone affixed to a corresponding point on the spider where the forces balance, with point A being affixed to the spider continuously all the way around cone 6.

5            Since the material of surround 8 is much more flexible than the material used for spiders, the horizontal forces applied to the outer edge of cone 6 is much smaller than the horizontal forces applied by the stiffer spider at point A. This results in a minimal, or zero bending moment at point B while there may still be a small bending moment at point A resulting from the surround since the horizontal component of the tensile force  
10   applied by the surround is balance by a force applied on the other side of the speaker cone. Thus, the possibility of distortion of cone 6 and the resulting sound being reproduced is very small and most likely not above the threshold of the human ear.

             It can be seen from Figures 2b and 2c, that the present invention provides a  
15   speaker design wherein the forces on the cone are substantially balanced at all times throughout the travel of the cone. As is the case with respect to Fig. 1b, in the configuration of Fig. 2b everything is at rest with the position of cone 6 is determined by the weight of cone 6 and voice coil tube 12, and the flexibility of surround 8 and spiders 10' and 10".

20            Figures 3a-3c show another shallow speaker design that is similar to that of Figures 2a-2c with cone 6 of Figures 2a-2c replaced with a flat cone or baffle 6' formed with a ring 16 extending from the bottom side of baffle 6' and having an internal diameter that is greater than the outside diameter of the largest components of magnet  
25   4. Ring 16 can be attached to the underside of baffle 6' in a number of different ways, including, but not limited to, being molded with baffle 6' or fused or glued to baffle 6'. The lower extent of ring 16 then attaches to spider 10''' at a point where substantially equal tension will be applied to ring 16 by each of the two portions of spider 10''' (i.e., the portion between basket 2 and ring 16, and the portion between ring 16 and magnet

4). Of course, here, as in the previously described embodiment, spider 10''' can be either one continuous spider or two individual spiders, one to each side of ring 16, and the bottom of ring 16 is equivalent to point A in Figs. 2a-2c.

5 A passive radiator is like the speaker of Figures 3a-3c without the magnet and voice coil assembly, thus it can be seen that the same suspension technique lends itself to use in a passive radiator. While a passive radiator does not have a voice coil tube wobble problem, the entire baffle may wobble if the tension on ring 16 is unequal throughout the range of travel that it undergoes. That wobble could result in  
10 discernable distortion of the sound wave produced due to an uneven flexing of the baffle, and the side to side component of that wobble results in some energy being lost that could otherwise be delivered in the sound wave produced by the baffle.

Figures 4a-4c illustrate the three positions discussed above of a speaker with a  
15 concave cone of a third embodiment of the present invention. This speaker includes a deep basket 20 with a magnet assembly 22 in the center bottom portion of the basket, a concave cone 24 affixed at the center to voice coil tube 32, with voice coil 34 on the lower end thereof. Tube 32 surrounds the central portion of magnet assembly 22. Cone 24 is shown here having a center conical section 26 with the outer rim affixed to  
20 downwardly extending ring 38 and an outer conical section 28 flaring out from the top of ring 38 (it should be noted that cone 24 could have a simple conical shape with ring 38 attached to the bottom of cone 24). The outer rim of cone section 28 is attached to the mouth of basket 20 via surround 30. Within the lower portion of basket 20 there is shown an attachment point 40 that encircles and extends a short distance into the  
25 inside of the basket. From Figure 4b where the speaker is unenergized and cone 24 is in the static position, it can be seen that attachment point 40 is opposite the upper outer extent of magnet assembly 22 and the bottom edge of ring 38 which is approximately centered between attachment point 40 and the upper extent of magnet assembly 22. Additionally, there is a spider 36 (either a single piece or two pieces as

discussed above) having the outer edge attached to attachment point 40 and the inner edge attached to the upper extent of magnet assembly 22. Approximately in the center of spider 36, the bottom edge of ring 38 is attached. From Figures 4a-4c it can be seen that forces on the end of ring 38 are balanced at each point of attachment to spider 36 as discussed previously for other embodiments of the present invention; not the opposite side of the speaker as in the prior art.

Figures 5a-5c are each a profile slice of the center of another design of a deep basket speaker. This speaker includes a deep basket 50 with a magnet assembly 52 in the center bottom portion of the basket, a concave cone 54 affixed at the center to voice coil tube 60, with voice coil 64 on the lower end thereof. Tube 60 surrounds magnet assembly 52 with the magnet assembly having an upper extending central pillar 58. The outer rim of cone 54 is connected to the mouth of basket 50 via surround 56, and the center of cone 54 is attached to the upper edge of voice coil tube 60. Within the lower portion of basket 50 there is shown an attachment point 66 that encircles and extends a short distance into the inside of the basket. From Figure 5b where the speaker is unenergized and cone 54 is in the static position, it can be seen that attachment point 66 is opposite both the junction of cone 54 and voice coil tube 60 as well as the top of pillar 58 of magnet assembly 52. There is also a spider 62/62' strung between attachment point 66 and the top of pillar 58 through the junction of cone 54 and tube 60. Spider 62/62' can be either a single spider or two spiders as discussed above. From Figures 5a-5c it can be seen that forces on the junction of cone 54 and the top of tube 60 are balanced at each point of attachment to the spider by spider portions 62 and 62' as discussed previously for other embodiments of the present invention; not the opposite side of the speaker as in the prior art. This embodiment is presented to illustrate that both portions of the spider of the present invention have to be beneath the cone of the speaker and all portions of the spider do not have to be outside the voice coil tube.

It is to be understood that in each of the embodiments illustrated in the figures and discussed herein the speaker has been shown in cross section as is typically done for ease of visualizing the speaker constructions. Additionally it is to be understood that spider, and spider portions, totally and continuously surround the central portion of the speaker or passive radiator.

From the variety of speaker configurations disclosed above that incorporate the balanced spider of the present invention, it is clear that the balanced spider can be incorporated into virtually all speaker designs. Thus, the present invention, simply stated, is the balancing of the forces at each point of attachment with the spider without one side being balanced from the opposite side of the speaker as in the prior art. Thus, the invention is not to be interpreted as being limited to only the speaker designs illustrated here, but to include any speaker design.

While the invention has been described with regard to several specific embodiments. Those skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the invention. One skilled in the art will also find it obvious to extend the techniques discussed to a passive radiator, as well as any speaker or passive radiator configuration. This is true since a passive radiator is basically the same as a speaker without the electromagnetic engine for moving the diaphragm or baffle of the passive radiator.